Idaho National Engineering and Environmental Laboratory

Hydrogen Production from Nuclear Energy

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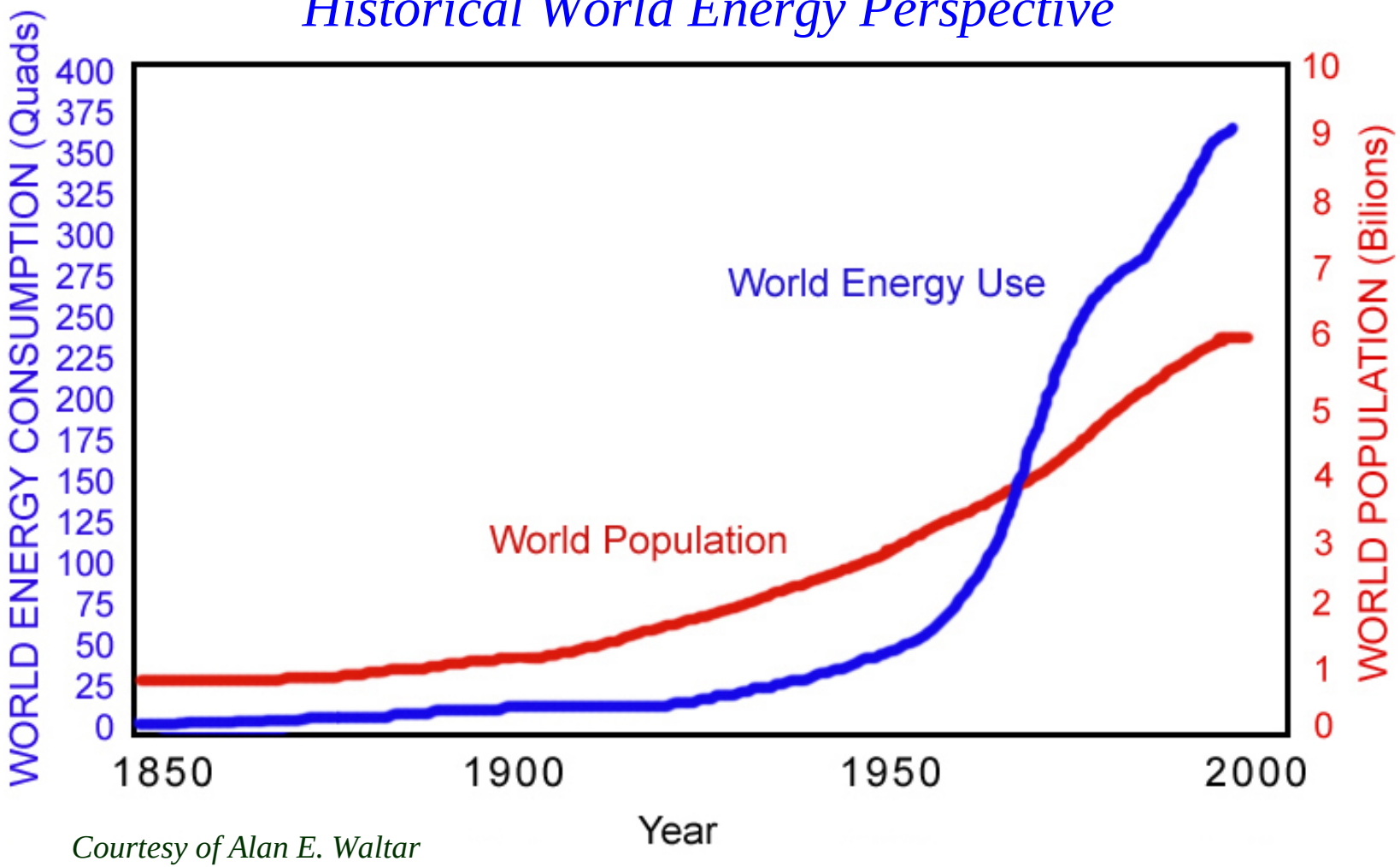
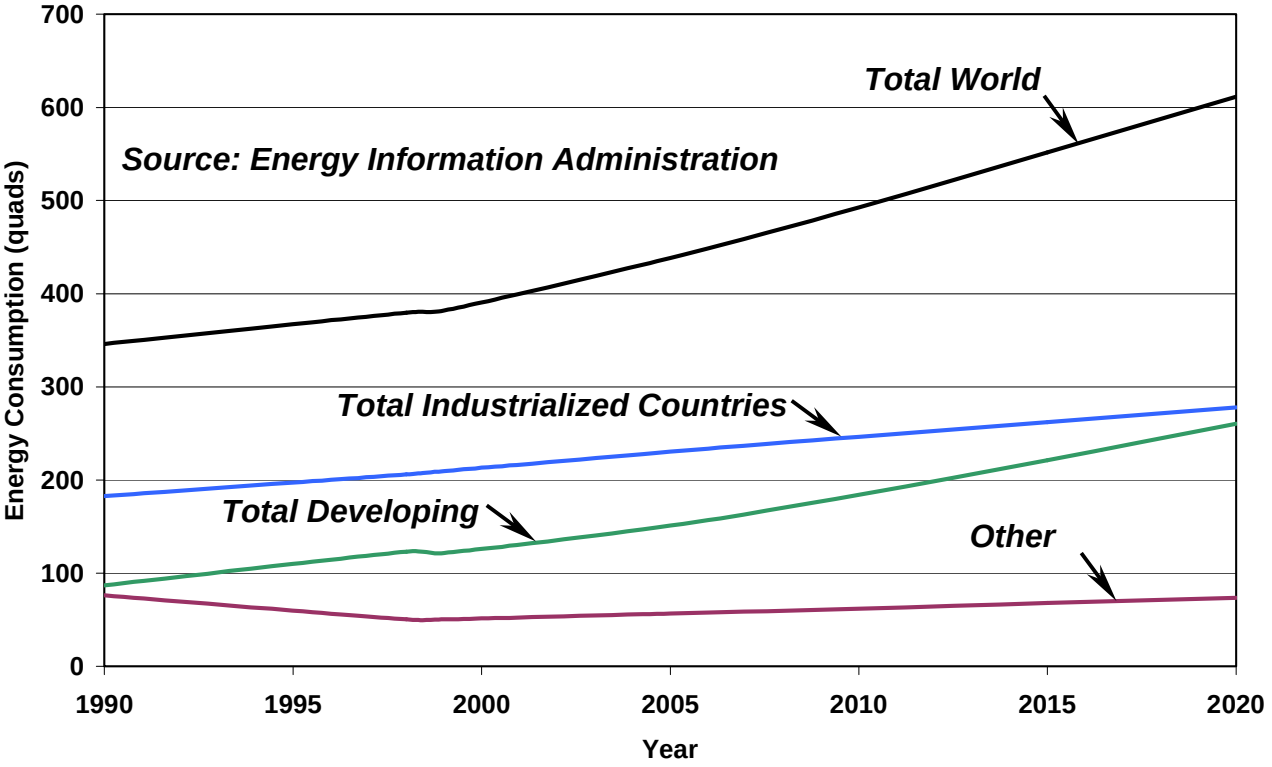
Energy Needs for Sustainable Development

Historical World Energy Perspective



Courtesy of Alan E. Waltar

World Energy Demand



World Energy Perspective

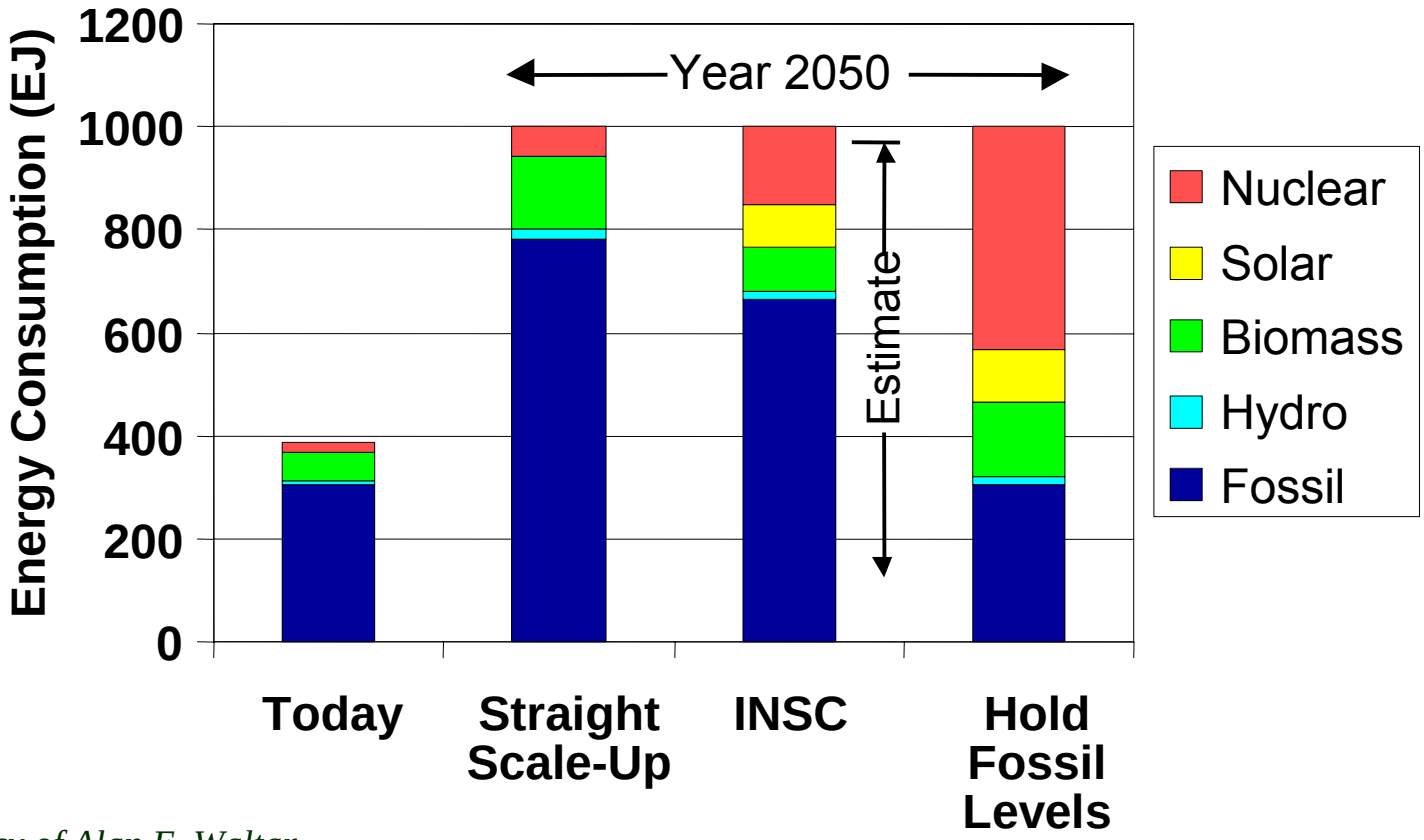
Projected growth over the next half century
(International Nuclear Societies Council)

Year	Population (Billions)	GJ/Person	Total Energy (EJ)
2000	6	67	400
2050	10	100*	1000

* NOTE: U.S. Today ~ 300 GJ/Person
100 GJ/Person represents 5 times increase for poor nations

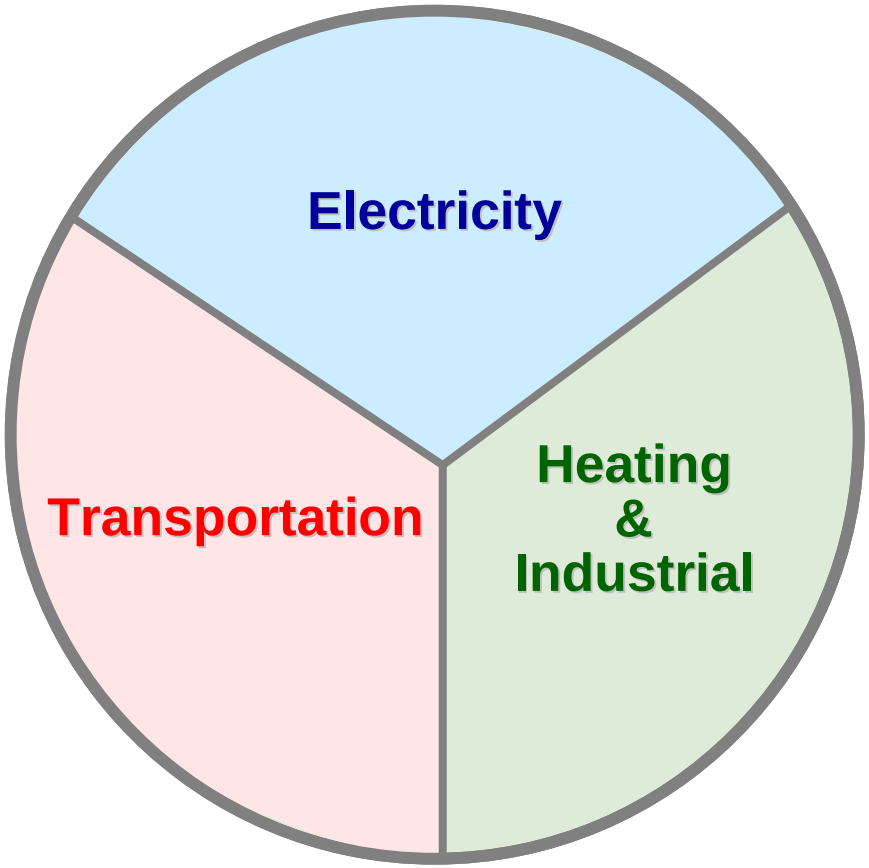
Courtesy of Alan E. Waltar

Global Energy Mix
(Options for the Future)



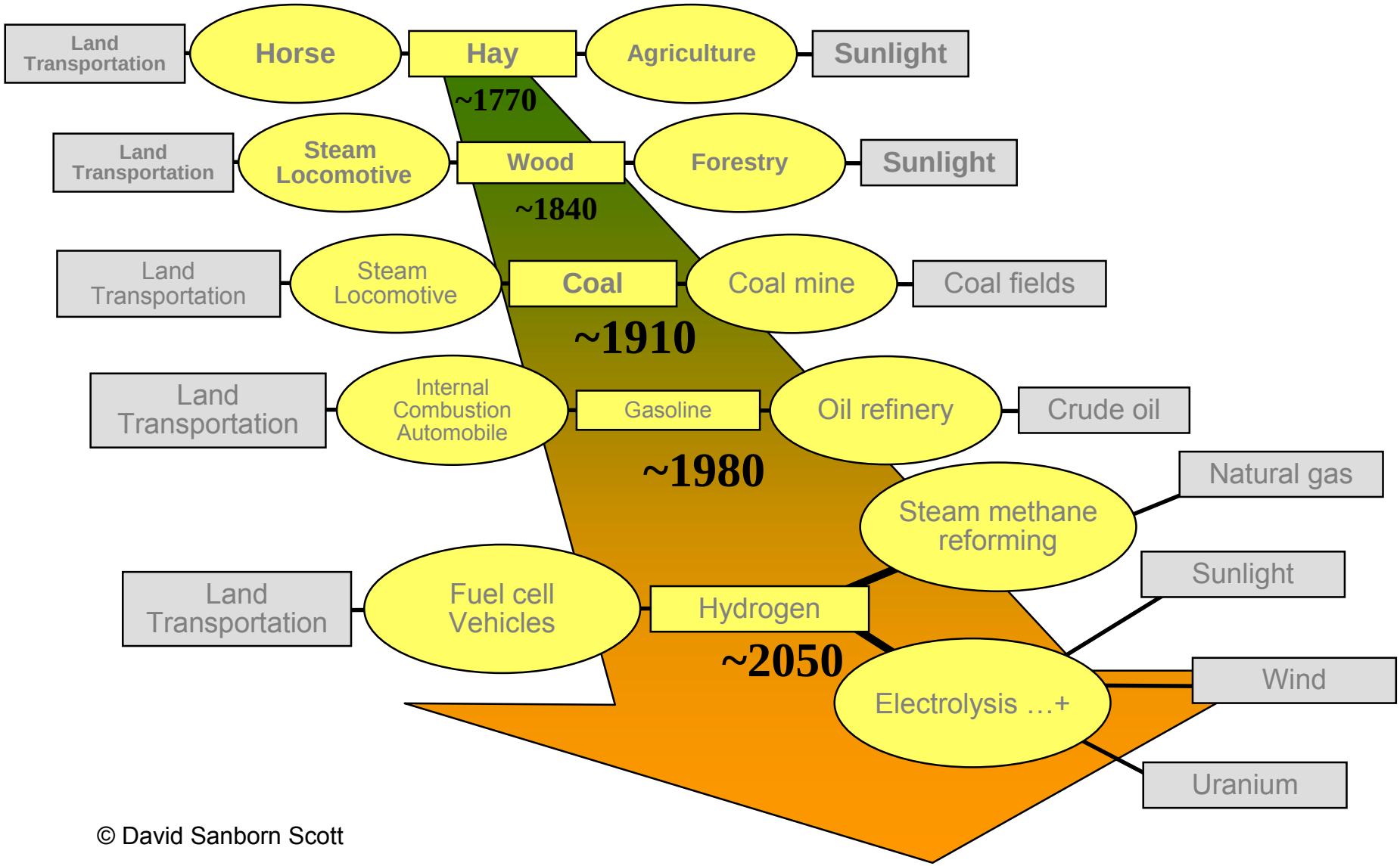
Courtesy of Alan E. Waltar

Uses of Primary Energy



Gen IV provides the opportunity for nuclear power to impact the other primary energy use sectors

Land Transport: $\Delta t \cong$ 70 years



Present Hydrogen Consumption

- ***Petroleum refining***
  - *Sulfur removal*
  - *Opening of benzene rings*
  - *Breaking of long-chain hydrocarbons*
- ***Anhydrous ammonia production***
- ***Chemical industry***
- ***Annual consumption***
  - *U.S.: 12 million t H_2/yr (47 GWth if burned)*
  - *World: 50 million t H_2/yr (200 GWth if burned)*

(50 million t H_2/yr would require 390 GWth input to a thermochemical process)

The Emerging Needs for Hydrogen

"The Hydrogen Economy"

- **The "transportation fuel of the future"**
  - *28% of US energy used for transportation*
  - *Essential for overall CO_2 reduction*
- **Distributed power – neighborhood fuel cells**
- **Rapid hydrogen-demand growth to produce clean fuels from lower-grade crude oils**
- **Within 10 to 20 years, the energy to produce hydrogen in the U.S. may exceed current energy production from nuclear power**

Nuclear Can Do More: Hydrogen for Transportation

Nuclear has already largely displaced oil for electricity generation

In the future, H_2 produced by nuclear can reduce oil use for transportation and dramatically reduce our reliance on foreign oil imports

One nuclear fuel pellet could make enough hydrogen for 220 cars to go 100 miles

Methods for hydrogen production using nuclear energy

- Steam methane reforming using nuclear energy for the endothermic heat of reaction
- Conventional electrolysis using nuclear-generated electricity
- Thermochemical cycles for water splitting
- Hybrid cycles combining thermochemical and electrolytic steps
- High temperature electrolysis using nuclear electricity and heat

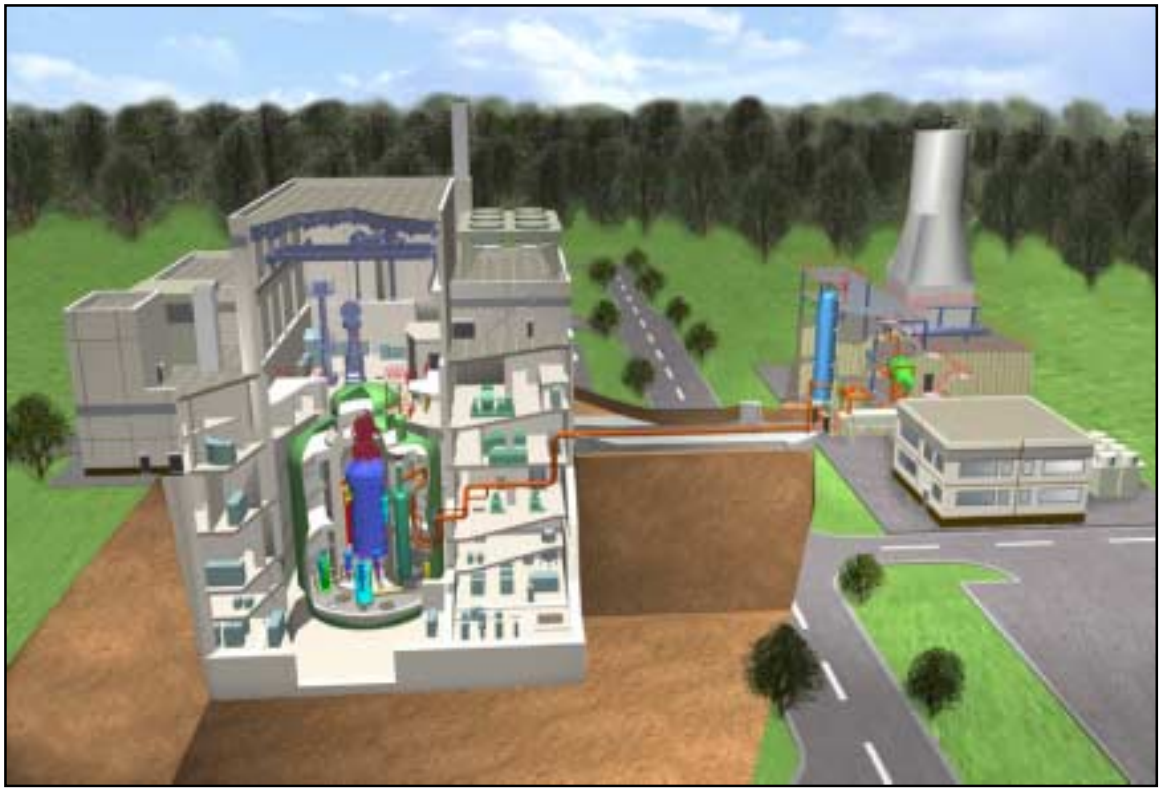
Steam methane reforming using nuclear energy for the endothermic heat of reaction

$$CH_4 + 2\,H_2O + 185\ kJ \leftrightarrow CO_2 + 4\,H_2$$

(80% of CH_4 converted at 800° C)

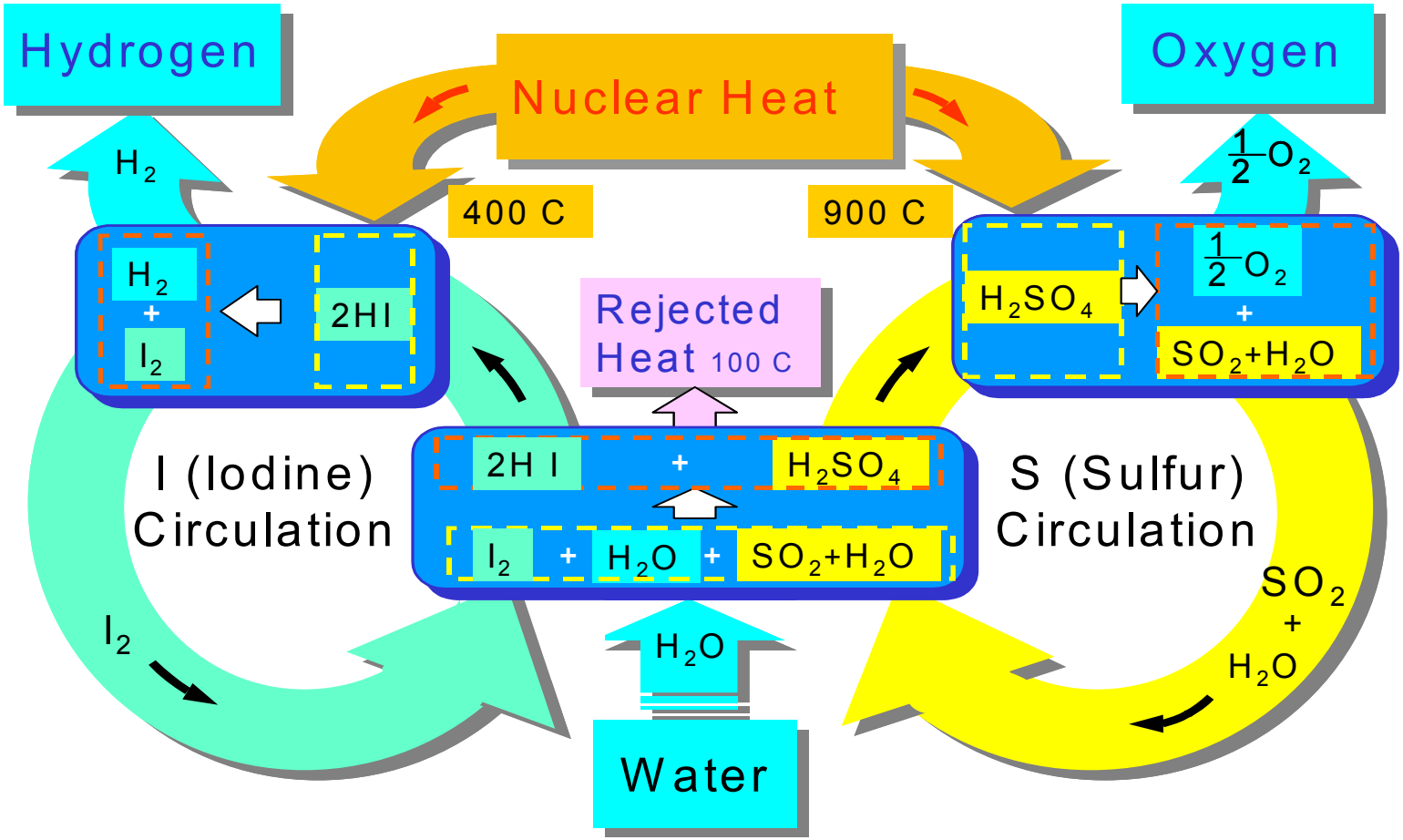
- *Advantages*
  - *Existing technology*
  - *Avoids methane use to produce steam*
  - *Easier to sequester CO_2 (than CO_2 from burning methane)*
- *Disadvantages*
  - *Still uses large quantities of methane (natural gas)*
  - *Releases large amounts of CO_2*

High Temperature Test Reactor



Using HTTR for NPH demonstration

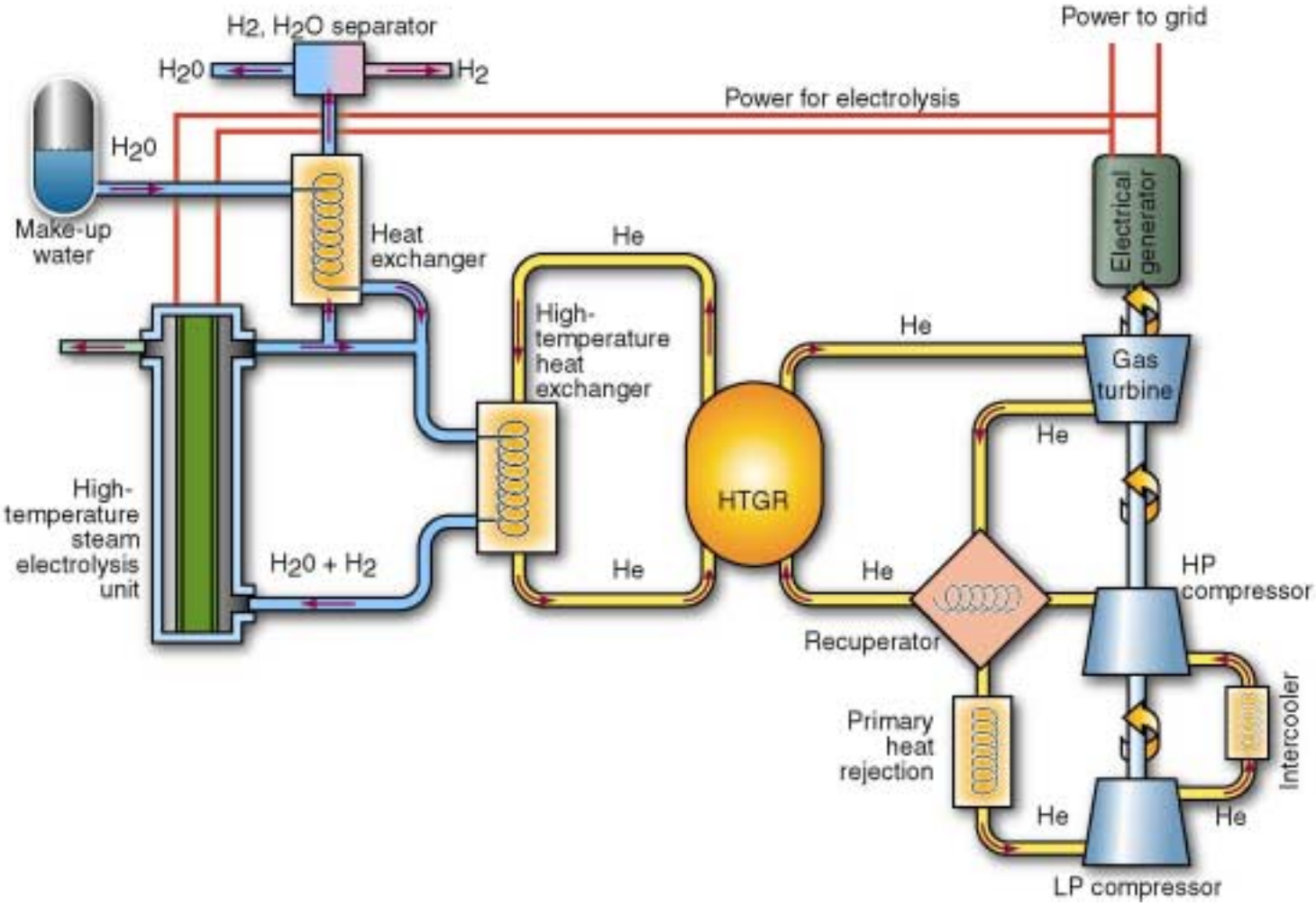
Thermochemical Water Splitting



High temperature electrolysis using nuclear electricity and heat

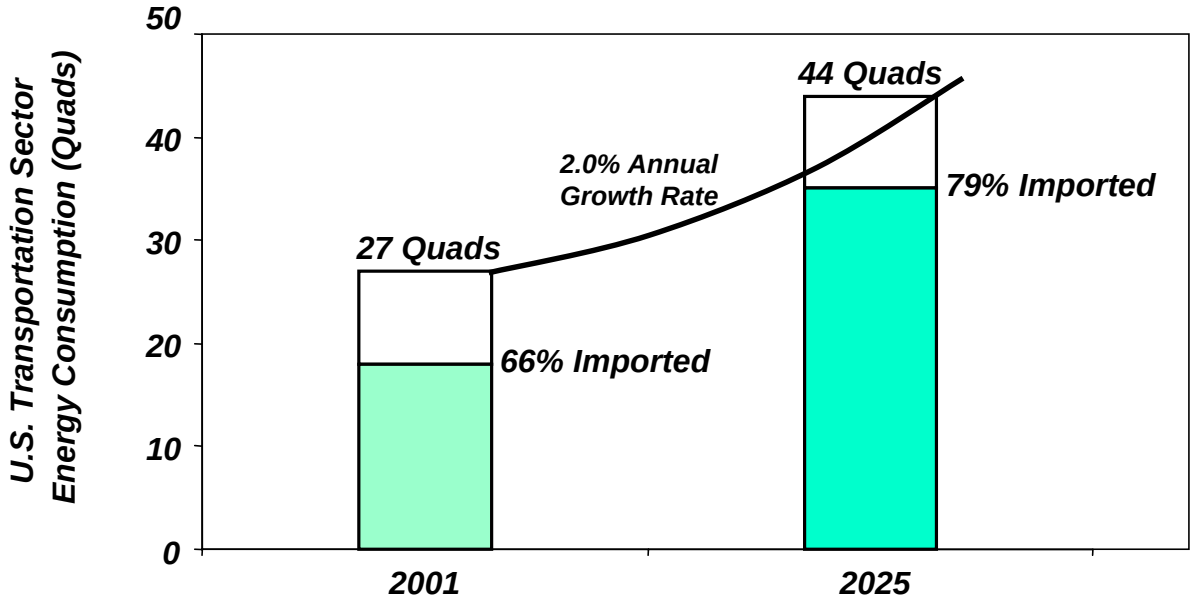
- *Advantages*
  - *Builds on existing Solid Oxide Fuel Cell technology*
  - *Lower operating temperatures than thermochemical cycles*
  - *Less corrosive operating conditions*
- *Disadvantages*
  - *Will have lower efficiencies than thermochemical cycles*

High Temperature Electrolysis using a Nuclear Reactor Heat Source



Potential for Nuclear in Transportation

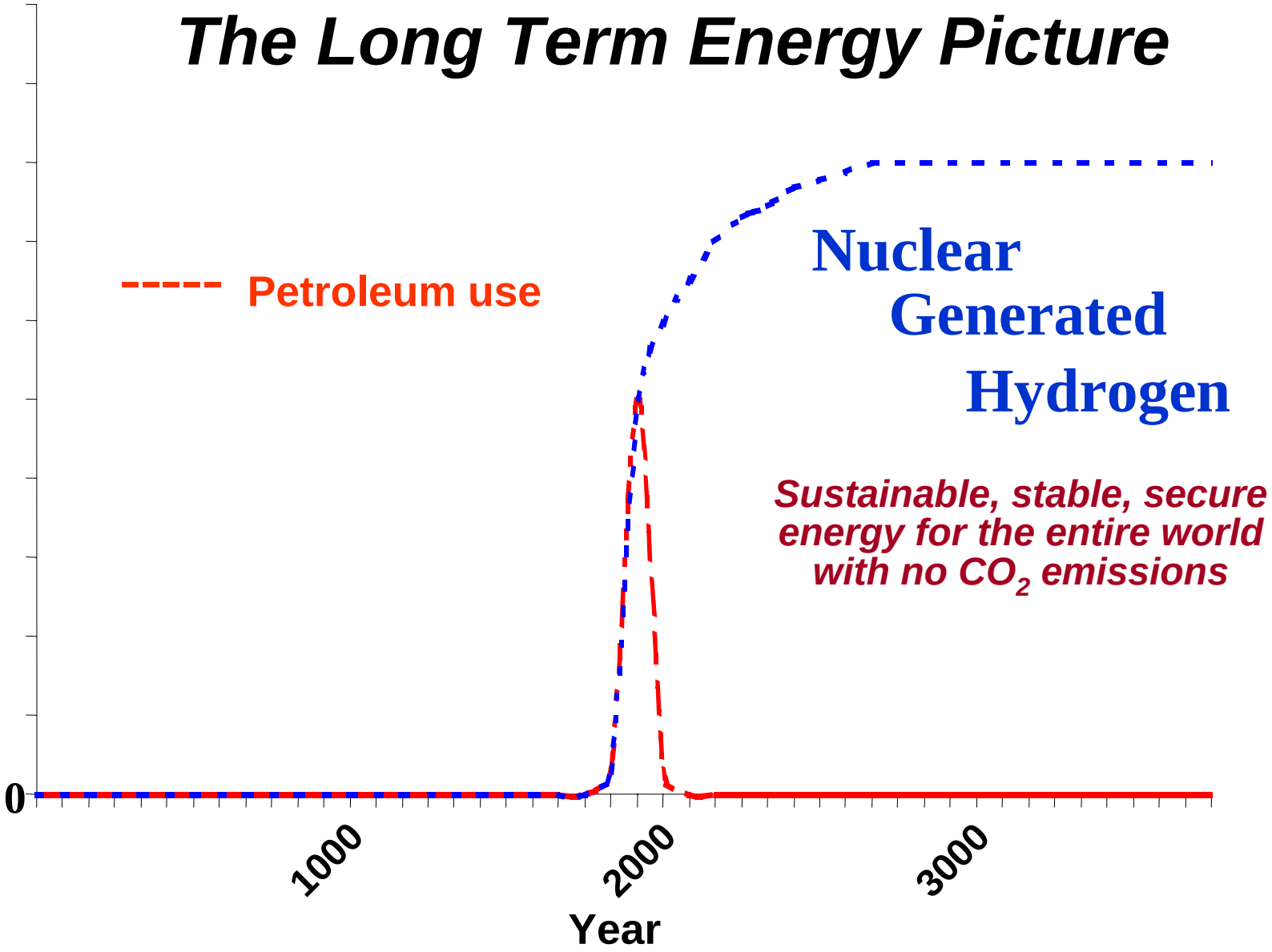
Growing U. S. Transportation Sector Energy Demand and Imports



Source: 2003 Annual Energy Outlook

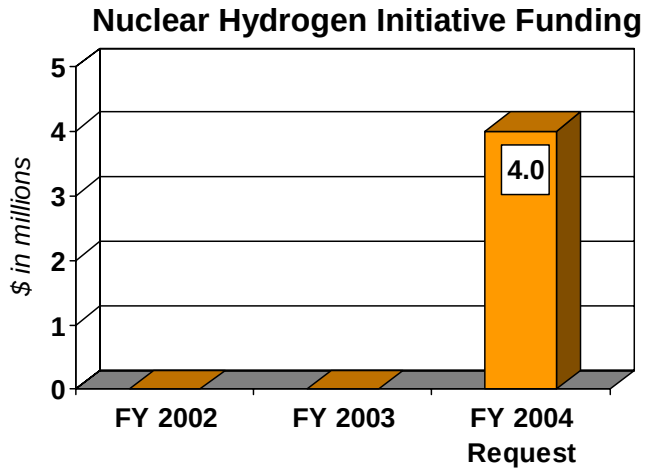
- ***Transportation sector growth leads electricity & heating***
- ***Outlook is for a disproportionate increase in imports***
- ***Increasing dependence on imports clouds the outlook for energy security and stability***
- ***Hydrogen can contribute if production-distribution-end use issues can be successfully addressed***

The Long Term Energy Picture



Nuclear Hydrogen Initiative: Developing Nuclear Energy Systems for Clean and Abundant Hydrogen Production

- **Nuclear energy systems offer opportunity for economical, clean, and abundant source of hydrogen**



Planned Accomplishments in FY 2004

- **Complete a Nuclear Hydrogen Technology Roadmap**
  - **Built on National Hydrogen Energy Roadmap and inter-office cooperation**
  - **Define R&D required to develop an integrated nuclear hydrogen production plant**
- **Develop concept for an integrated nuclear hydrogen production system**
- **Initiate R&D on high temperature and corrosion resistant materials for thermo-chemical process**

The Nuclear Hydrogen Outlook

- Demand for hydrogen is large today and growing 4-10%/yr
- President Bush has announced a FreedomFUEL program
- Long-term, a 30 million t/yr U.S. hydrogen supply would be able to serve one-quarter of our gasoline use
- Nuclear energy required for this would be 225 GWth
- Thermochemical cycles have highest efficiency but most daunting operating conditions
- Electrolysis is promising, particularly in the near term